Sustainable Renovation of Public Buildings in Europe with Structural Glazing Technique

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Abstract— **The paper discusses the contribution of structural silicone glazing to sustainable renovation by providing three examples of projects owned by the European Union Administration that underwent successful sustainable renovation effort during the past years.**

Keywords— ***Sustainable renovation, European Union, structural silicone glazing, silicone sealant, Brussels***

I. STRUCTURAL SILICONE GLAZING AND ITS CONTRIBUTION TO SUSTAINABLE RENOVATION

Structural silicone glazing may be defined as a system of bonding glass or other facade panels to a building's structural framing by utilizing a high strength, high performance silicone sealant designed and tested for this application [1]. By substituting a conventional, mechanically fixed glazing with structural silicone glazing technology, an architect contributes to sustainable architecture – the environmental, social, economic, and design quality of the building.

Silicone structural glazing offers creativity and design freedom, combined with lower life cycle cost and improved thermal and acoustic performance of the facade. The elastic silicone placed between the glass and the supporting metal frame provides a thermal break, minimizes air infiltration, and contributes to the decoupling and damping of vibrations, resulting in the potential for more energy-efficient and improved acoustic performance. Silicones resist natural degradation by the environment and have inherently higher durability and longer service life than their petroleum-based organic counterparts. Longer service life translates into lower life cycle cost.

In our evaluations, thermal modelling has repeatedly demonstrated the positive impact of silicone structural glazing versus mechanical fixation on the thermal performance of facades [2,3]. Not surprisingly, the thermal performance of the insulating glass unit also contributes to the overall thermal performance of the facade. Warm-edge spacers, such as those based on silicone foam, as well as filling of the cavity of the insulating glass unit with a noble gas, both contribute to the performance of the facade. Replacing a conventional, mechanically fixed glazing system with structural glazing can improve the U-value of the facade by as much as 0.2 W/ (m2K). The energy demand of the building can be further reduced by lowering its air infiltration rate [4].

The durability of the bulk and adhesion properties of silicone in structural glazing ensures lower infiltration rates over the service-life of the building as compared to mechanically fixed facade glazing that utilize organic gaskets. Structural silicone glazing may be the only curtain wall system that can reliably weatherproof a curtain wall during its entire life-time [5]. Silicone sealants also excel in their glass adhesion and resistance to sunlight, making them the material of choice for structural and commercial glazing as well as demanding roof glazing applications. Recent developments on insulating glass units (IGU) have demonstrated that argon-filled silicone dual sealed IGU's can reliably meet the stringent requirements for moisture penetration resistance and gas retention as defined in the national and international industry standards [6,7]. In combination with warm-edge spacers, silicone secondary sealants provide improved energy efficiency and reduced condensation risk at the edge of the insulating glass unit.

Structural silicone glazing, thus, offers the following enhancements in sustainable renovation projects:

Energy savings: Improved thermal and air-tightness performance of the curtain wall (reduced HVAC requirements), natural lighting (reduced artificial lighting requirements)

Increase of comfort: Natural lighting, exterior noise reduction (improved acoustic performance of curtain wall)

Healthy working environment: Low volatile organic content (VOC) of silicone sealants and adhesives

Extension of building life cycle: Increased longevity of curtain wall

Economized exploitation: Lower life cycle cost

Environmental protection: Reduced carbon footprint (versus conventional curtain wall) due to lower operational energy requirements

Brussels Case Histories – Examples of Successful Sustainable Renovation of Buildings with Structural Silicone Glazing Technique

Brussels, the capital of Belgium, has become one of the important administrative centres in Europe with a concentration of European institutions and is often considered to be the de facto capital of the European Union, as the city hosts the official seats of the European Commission, Council of the European Union, European Council and a second seat of the European Parliament.

Contrary to most other European cities, Brussels has focused its development of tall buildings during the past 10 years on the sustainable renovation of obsolete buildings or the urban renewal of derelict tall building zones. To a significant extent this trend is driven by the European Union's interest in

role-modelling sustainable renovation and urban renewal with their buildings. Therefore, much effort has gone into urban contextualization and into implementing state-of-the-art sustainability features in these buildings. The renovated or newly built towers include an array of energy saving features, such as active double-skin facades and wastewater recovery processes, which use advanced biological purification processes.

The paper discusses some exemplary sustainable renovation projects initiated by the European Union that have been completed recently in the city of Brussels and in which the structural silicone glazing technology has been utilized to enhance their sustainability features. The sustainable renovation of these buildings has provided the city of Brussels with an exciting and innovative means of exploiting the full potential of structures, which may otherwise appear unattractive and outdated.

A. Madou Plaza Tower, Brussels

Originally completed in 1965, Madou Plaza is one of the tallest buildings in Brussels. Its renovation between 2002 and 2006 is probably one of the most ambitious of its kind ever undertaken in the city. Completely redesigned in respect to its function, logistics, and relationship to its surroundings, the 34-story 120 m high building has been entirely rebuilt around its original structure [8]. For instance, the existing floors were extended by an additional 80 cm to transform the straight existing facade into the new, curved facade. The increase in office surface area required a complete building reshape and structural reinforcements: welding shells on certain steel beams, adding concrete columns in the basements, and some strengthening of the foundations.

Fig.1 Madou Plaza Building (as seen from Parc de Bruxelles), Source: J. Logan, Wikipedia Commons, http://en.wikipedia.org/wiki/File:Tour_Madou_Brussels.jpg

The European Commission bought the building on 13 March 2006 and inaugurated it on 19 April, when its 1500 employees moved in. Based in the Madou Plaza building today are the Directorates-General for Communication, Informatics, and Education and Culture, as well as the Executive Agency for Competitiveness and Innovation.

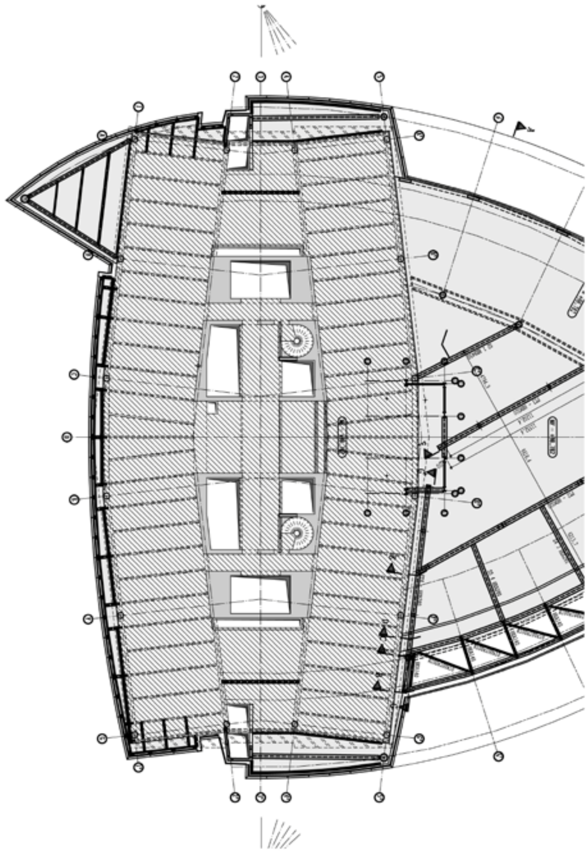

Fig.2 Madou Plaza Building (Floor Plan) – the shaded section indicates the existing Madou Plaza tower limits before renovation, source: ASSAR Architects, Brussels, lead and design architect/Waterman TCA

Some 8,000 m2 of new construction at the base have created a podium for the existing 32,000 m2 tower, expanding the tower to a total capacity of 40,000 m2 of prime office space. The podium houses a spectacular, 13-story atrium, the highest in Brussels. The atrium serves as a welcome hall, allows natural light to flood the offices on the lower floors and acts as a communication hub for the rest of the building. Facing the atrium on one side is a 193-seat auditorium; on the other side, there is a 150-seat cafeteria. A grand staircase leads to the first floor restaurant, which benefits from views overlooking the atrium on one side and from panoramic views of the city on the other side.

Fig.3 Madou Plaza Building Atrium, Source: ASSAR Architects, Brussels, lead and design architect (Archi 2000), Photo: Marc Detiffe

Prior to its transformation, there was no plaza in front of the building. The back of the tower was adjacent to derelict townhouses and workshops left abandoned for years.

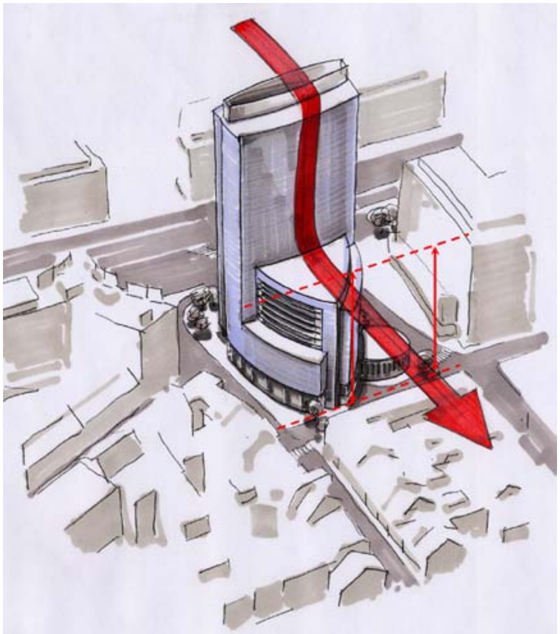

Fig.4 Plaza Building and Surroundings, Rendering showing the aerodynamic principles as well as the contextual volumetric approach, Source: ASSAR Architects, Brussels, lead and design architect (Archi 2000)

The extension of the building was made possible by the client acquiring the adjacent site and the City of Brussels then suggested the idea of buying a portion of the boulevard so as to allow for the creation of a real plaza in front of the tower. In terms of urban renewal, the whole neighbourhood has been redeveloped with new retail and housing streets created next to the tower. Car and pedestrian circulation has been redistributed for greater efficiency and safety.

Fig.5 View of the Double-Skin Facade (DSF) of Madou Plaza Building, © European Union, 2009, Architectural Company ASSAR

In order to maximize the comfort of the building's occupants, all offices are fitted with cooled ceilings. The entire ceiling surface acts as a cooling radiator due to the circulation of chilled water in tiny tubes located behind perforated metal panels. The semi-reflective, active 15,000 m2 double-skin facade (DSF) has a four-sided silicone structurally glazed outer layer based on double-pane insulating glass units. The DSF features operable windows (one in two windows are operable) in which the inner and outer layers of the facade can be opened horizontally as one unit to the exterior, allowing the occupants to take full advantage of natural ventilation. The solar control glass installed in the DSF provides good sun glare protection, while providing good views of the city and allowing natural light to be utilized for lighting wherever possible, making Madou Plaza a pleasant place to work.

Sealing of the four-sided operable structurally glazed units was carried out with a structural silicone sealant, which was used to bond the IG units to the anodized aluminium frames. In order to achieve sufficient resistance against ultraviolet (UV) light, the insulating glass units were also sealed with a silicone secondary seal.

The Madou Plaza Tower won the prestigious MIPIM Award in Cannes in 2006 in the 'Refurbished Office Buildings' category. The MIPIM Awards recognize excellence and innovation in the real estate arena and attract global attention from key industry players.

B. Charlemagne Building, Brussels

The building was originally designed by Jacques Cuisinier and constructed in 1967 at the same time as the Berlaymont Building and typified the style of the period: a heavy concrete exterior and an oppressive interior which, whilst maximizing the available space, paid little or no attention to environmental impact, energy efficiency, or even the conviviality of the surroundings, when compared to modern thinking. Initially, the building was occupied by the European Council. During the mid-1990s, the European Quarter, 400,000 m2 of EU

Commission property stretching from the Brussels ring to the Schuman area, had been identified as a strategic development hub with the intent to give the European Quarter more liveable, human attributes. Previous attempts had fallen short of this target.

In 1995, the Council moved out to a different building, allowing the Charlemagne Building to be renovated. One of the key themes of the renovation was the successful integration of the renewed building with the fabric of the surrounding city, characterized by the presence of constructions of different ages and styles. The old Charlemagne Building already housed the various administrative organs of the European Community; therefore, the renovation was intended not only to expand an existing building, but also to provide structures, which would improve its efficiency.

The renovation project was developed by Chicago architects Murphy and Jahn, renowned for their functional and highly innovative creations, in which professional style is harmoniously combined with creativity [9]. The architectural solution had to have minimum impact so as not to disturb the already fragile balance of the neighbourhood: the only way to do this was with glass walls. The renovation was completed in 1998. The new building is covered with a thin "skin", a curtain wall which reflects the characteristics of its location and completely blends in with its surrounding context.

The renovated Charlemagne Building, designed to integrate more effectively with its environment, employs wide expanses of glass facade to allow greater use of natural light. All concrete walls have been replaced by a structurally glazed facade and a point-fixed (bolted) glazing system, which ensure the environmental integrity of the building, such that it now meets European energy efficiency standards. A new atrium has also been constructed using a bolted glass system. It replaces a single concrete supporting arm, thus further enhancing light penetration into the centre of the structure and creating a smooth transition from the exterior to the interior of the building.

Fig.6 Charlemagne Building in 1975, Source: Deutsches Bundesarchiv (German Federal Archive), B 145 Bild-F046067-0010 (this image was provided to Wikimedia Commons by the German Federal Archive (Deutsches Bundesarchiv) as part of a cooperation project, Photo: Wienke, Ulrich)

A silicone sealant was specified for the structurally glazed curtain wall, along with a silicone secondary edge seal for the insulating glass units. To maximize the potential of the Charlemagne design, the building concept demanded a very clear, high performance, low emissivity glass for the facade, used in conjunction with external glass fins. The design used a four-sided structural glazing system where the silicone has the dual purpose of bonding the structural joint whilst providing a weather seal around the panel.

A similar system, also using the structural silicone sealant, was utilized in the construction of the glass arch linking the two primary arms of the building. Furthermore, the versatility and adhesion capabilities of the structural silicone sealant meant that the product was used to rigidify the glass fins, via a silicone joint between the edges of the glass fins and the aluminium profiles. No other technique would have allowed the design of a sheer glass wall, forming an imposing sail-like shape.

Fig.7 Charlemagne Building, Source: www.istockphoto.com/

C. Berlayment Building, Brussels

The Berlaymont Building in Brussels, Belgium, headquarters of the European Commission, was originally built in 1969 on the site of a 17th century convent. By the early 1990s, it was obvious that the Berlaymont Building needed a complete renovation, because of outdated infrastructure, poor sealing and insulation, lack of daylight, and a huge asbestos threat. The European Commission specified a number of challenging sustainable development criteria: First, the original structure should be retained as much as possible. Second, the building should become a landmark in terms of energy efficiency, durability of the building materials used, ease of maintenance, and optimum natural light penetration into the building.

Evacuated in 1991 because of the asbestos-related safety fears and with renovation starting only in 1999, the Berlaymont Building finally emerged from white dust sheets in 2004 after a 13-year 1 billion € renovation program. The building now is a model of energy efficiency and adheres to all international and European guidelines. The intelligent, active facade employed in the renovated building deserves some more detailed discussion. High performance silicone sealants helped achieve this intelligent double-skin facade first by providing inherent durability and therefore improved life cycle cost and second by enabling a fail-safe construction system. The interior of the façade has floor-to-ceiling insulating glass units sealed with a silicone secondary sealant, while the exterior part consists of 21,000 m2 of mobile glass louvers bonded to the metal substructure by a structural silicone sealant.

Fig.8 Berlaymont Building, Brussels, Moveable External Louvers (seen from building interior), Source: J. Logan, Wikipedia Commons, http://en.wikipedia.org/wiki/File:Berlaymont_Blinds.JPG

The mobile louvers are controlled by a computer connected to weather sensors. The 'living' façade changes the position of the louvers depending on the position of the sun, the temperature, and wind speed. By doing so, it provides uniform natural lightning inside the building, prevents overheating of the building in summer due to solar gain, and works like a coat in cold winter [10].

The structural silicone sealant was used to attach the glass louvers to the movement mechanism and to provide life safety (i.e. glass retention) in the event of glass breakage. For the construction of the 2 m x 0.5 m louvers, the structural silicone sealant was used to bond laminated glass onto its aluminium frame and as an edge seal to improve the louvers' resistance to damage. The silicone sealant was chosen for (1) its unique strength to flexibility ratio, (2) its proven track record of durability and (3) its fire resistance. The silicone bonding had to undergo extensive and stringent testing in order to pass the requirements imposed by the Control Body in charge of safety and durability of the facade structure. The silicone bonding of the glass louvers had to undergo extensive testing as it also provides life safety by ensuring glass retention in the event of glass breakage.

Fig.9 Berlaymont Building, Brussels (as seen from Schuman roundabout, i.e., facing north-west), Source: © European Union, 2009

The variable positioning of the mobile glass louvers allows control of the energy flow into and out of the building. In addition, the active façade also reduces noise levels within the building.

With the gap between these louvers and the façade being 80-100 cm, creating vertical shafts, questions had been raised whether the position of the louvers would endanger the upper stories in case of a fire adjacent to the façade (see Figures 10 and 11). Special modelling of fire scenarios and smoke flows was performed in order to demonstrate the safety of the facade and the building [11].

Fig.10 Berlaymont Building, Brussels, Moveable External Louvers (louvers shown in different positions), Source: Dow Corning, photo: K. Yarosh

Fig.11 Berlaymont Building, Brussels, Moveable External Louvers (louvers shown during summer in almost closed position), Source: www.istockphoto.com/

In June 2005, a building energy efficiency certification based on the new European Directive on the Energy Performance of Buildings was issued for the Berlaymont Building in advance of the Directive's full implementation. All the certificates awarded gave "good" to "very good" energy efficiency ratings to the building, based on the fact that the energy consumption of the Berlaymont Building is about ½ of comparable buildings [12,13]. The Berlaymont Building demonstrates that sustainable façade construction is achievable.

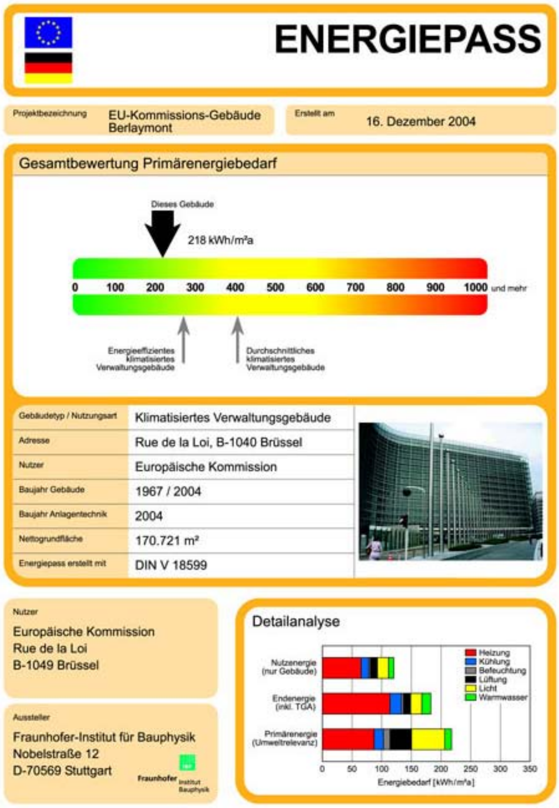

Fig.12 Energy Certificates for the Berlaymont Building Issued in 2005 (based on the German system), source: www.ibp.fraunhofer.de/wt/berichte/berichte_pdfs/final_report.pdf, reproduced with permission from Fraunhofer-Institut für Bauphysik (IBP)

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